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ULTRAFast SPECTROSCOPY AND LASERS.. R ALFANO ET AL

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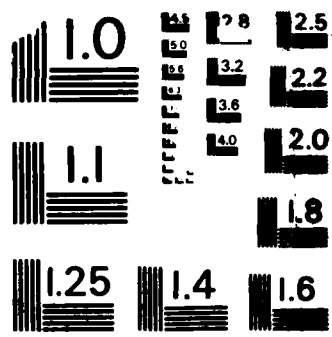
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**INSTITUTE FOR ULTRAFAST SPECTROSCOPY AND LASERS
ELECTRICAL ENGINEERING AND PHYSICS DEPARTMENTS**

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**Subpicosecond Optical Digital Computation using Phase Conjugate
Parametric Generators**

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Ph.D. Graduate Students: P. Delfyett, Yao Li

December 1985

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GOALS

The purpose of the research program is twofold, to investigate basic fundamental processes and develop subpicosecond phase conjugate four wave parametric generators, optical switches and processors. These devices will be tunable over a wide spectral range.

Significant progress has been achieved over the year in the project in the two areas. Work has been accomplished in new multispectral canonical optical logic elements using the four wave degenerate and Raman mixing mechanism and interference.

Areas of Progress

Progress has been achieved in four areas:

1). We have demonstrated the use of the Raman induced phase conjugate technique (RIPC) both to obtain strong Raman signals and to measure relaxation times in liquids and solids using picosecond laser pulses. We have obtained the picosecond RIPC spectra of carbon disulphide, benzene, nitrobenzene and calcite. By delaying one of the interacting pump beams relative to the other pump and probe beams we were able to determine, with picosecond resolution, the intensities of the phase conjugate beams at the Stokes frequencies as a function of time. This new time resolved spectroscopic method will not only allow to study the relaxation mechanisms of the materials used in new broadband switching devices but also ultimately to develop multispectral ultrafast optical processors.

2). A Sagnac interferometer switch (SIS) with an optical nonlinear material in its loop has been constructed to perform digital optical logic. Both the SIS input and output logic variables were picosecond optical pulses. Using various SIS interconnections, all sixteen two variable binary logic functions can be implemented and both parallel and sequential logic processing are possible. An optical binary full adder has been developed from the SIS and subsequently modified for use as an ultrafast optical sampling device.

3). A model using statistical electrodynamic techniques has been developed to investigate photon echo in intrinsic direct transition semiconductor materials. This model can be directly applied towards creating new techniques in ultrashort time measurements and to develop new optical logic devices. For example, to measure time differences between pulses in the range 10^{-14} - 10^{-13} s, such as in differential measurements due to a variation of the index of refraction of a medium, rotation of medium, etc. it is sufficient, following this model, to measure the intensity of the echo generated by the incoming two pulses. Other potential applications include optical digital computation since all binary logic functions can be implemented using logical switches built around the photon echo effect with the possibility of 10^{12} operations per second.

4). A new time domain phase conjugate autocorrelator has been developed . In this new device three beams derived from the same initial laser pulse interact in a nonlinear medium to produce a backward signal wave in a 90° phase conjugate geometry. The pulse direction is determined from the spatial width of the phase conjugate beam emerging from the interaction region. The range of the pulse durations that can be measured can be easily changed from subpicosecond to hundreds of picoseconds. An important characteristic of this new technique is that, depending on the nonlinear medium, one can obtain information about the intensity or about the coherence correlation function of the laser pulse .

Future Directions

I) FUNDAMENTAL INVESTIGATIONS AND DEVICES

Fast nonlinear optical switches and logic devices can only be build with materials with large nonlinear coefficients and ultrafast relaxation dynamics. The main trust during the second year of the grant will be toward investigating the nonlinear coefficients, measuring vibrational relaxation times, and determining carrier energy , momentum relaxation and phonon dephasing times in neat liquids, polymers, solution of dyes, and semiconductors, using the four wave mixing techniques developed during the first year.

The experiments to be performed are :

1) Polymers, because of their large nonlinear coefficients are among the most promising materials. We plan to measure, using the phase conjugation technique, the magnitude and response time of coefficient X^3 for polyacetylene, polydiacetylene and other polymers at different wavelengths. We will also study the effect of the proximity of a resonance absorption band on the magnitude of the nonlinear coefficient X^3 for a fixed wavelength. In polydiacetylene the absorption band will be moved relative to the excitation wavelength by changing the pH of a water solution of the polymer.

2) Similar experiments will be carried out with semiconductors. We plan to measure X^3 in bulk semiconductors such as GaP, CdS, ZnO etc. The same samples will be studied in powder form ($\approx 10 \mu\text{m}$ particles) where a substantial increase of X^3 is expected due to surface nonlinear effects. Phase conjugation technique will also be used to study microstructures such as GaAs/GaAlAs and CdTe/CdMnTe.

3) The time resolved Raman induced phase conjugation (RIPC).technique will be used to measure vibrational relaxation times in liquid nitrogen and in different dye solutions. Phonon dephasing times will be studied in GaP, CdS, and LiNbO₃

4) The phase conjugation bandwidth and pulse duration will be investigated by using the picosecond super continuum as the probe beam and two monochromatic counter propagating pump beams.

5) The angular dependence of the phase conjugation process will be investigated by changing the angle of incidence of the probe beam upon the phase conjugate mirror.

6) Pulse compression is needed to perform the time resolved experiments since shorter laser pulses are necessary to achieve high resolution. Different techniques will be tried separately or in combination to shorten the YAG pulse duration from 30 ps to few picoseconds. They are: the selection of a pulse in the back of the train, compression to the coherence lifetime of the laser pulse by reflection off a phase conjugate mirror, broadening, chirping and compression using self phase modulation (SPM) in a nonlinear medium and a pair of grating.

7) Experiments will be performed to construct all proposed canonical SIS logic elements. Switching materials, such as multiple quantum well structures and polymers, will be studied as the active element.

8) A grating type SIS will be investigated and the enhancement of visibility versus. The pulse broadening will be studied.

9) A binary optical SIS sampler will be implemented.

Publications

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- 3) G. Eichmann and H. J. Caufield, Optical Learning (Inference) Machines, Applied Optics 24, 2051 (1985).
- 4) G. Eichmann, Y. Li, R. R. Alfano, Digital Optical Logic of Sagnac Interferometer Switch, (submitted).
- 5) G. Eichmann, Y. Li, R. R. Alfano, Pulse Mode Laser Sagnac Interferometry with Applications in Nonlinear Optics and Optical Switching, (submitted).
- 6) R. Dorsinville, P. Delfyett, R. R. Alfano, Time Resolved Picosecond Raman Induced Phase Conjugation in Liquids and Solids, (submitted).

Conference Paper

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